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Horizontal Variability of the Marine Boundary Layer Structure Upwind of San Nicolas Island During FIRE, 1987

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The Naval Ocean Systems Center ~~(NOSC)~~ airborne platform was used to determine the representativeness of island-based measurements to upwind open ocean conditions. Large differences existed in the meteorological profiles between the open ocean conditions and those taken near the island. A higher concentration of surface-based aerosols existed at the island. The vertical optical depths at the island were not significantly affected by this surface-based aerosol layer. Sea surface and cloud top temperatures near the island did not in general represent those observed upwind. Keywords: [illegible]

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SUMMARY

OBJECTIVE

Use the Naval Ocean Systems Center (NOSC) airborne meteorological platform to determine the representativeness of island-based measurements to upwind open ocean conditions.

RESULTS

Differences were observed but cannot be uniquely identified to a specific island effect, especially since upwind fluctuations bound the island measurements.

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INTRODUCTION

During June and July, 1987, the Marine Stratocumulus Intensive Field Observation Experiment of FIRE* (reference 1) was conducted in the Southern California offshore area. FIRE is a cloud research program for validating and updating the International Satellite Cloud Climatology Project (ISCCP) database and cloud/radiation parameterizations used in the general circulation models. The Naval Ocean Systems Center (NOSC) airborne platform was used during FIRE to investigate the low-level horizontal variability of the marine boundary layer structure. Flights were made near San Nicolas Island (SNI) to determine the representativeness of SNI-based measurements to upwind open ocean conditions. The NOSC airborne meteorological platform made three flights during FIRE. Two were made during clear sky conditions (19 and 23 July), and one during low stratus conditions (15 July). This report addresses the boundary-layer structure variations associated with the stratus clouds of 15 July 1987.

The prescribed flight pattern for the NOSC aircraft consisted of two upwind radial legs as shown in figure 1. On each of the legs, flights were made at constant altitudes of 100 and 4000 feet. Spirals were made at each radial endpoint and midpoint. Parameters recorded by the NOSC aircraft included air temperature (AT), relative humidity (RH), sea surface temperature (SST), cloud-top temperature (CTT), and aerosol extinction profiles. All flights were coordinated with the SNI ground-based platforms and the NPS Research Vessel *Point Sur* to ensure simultaneous measurements.

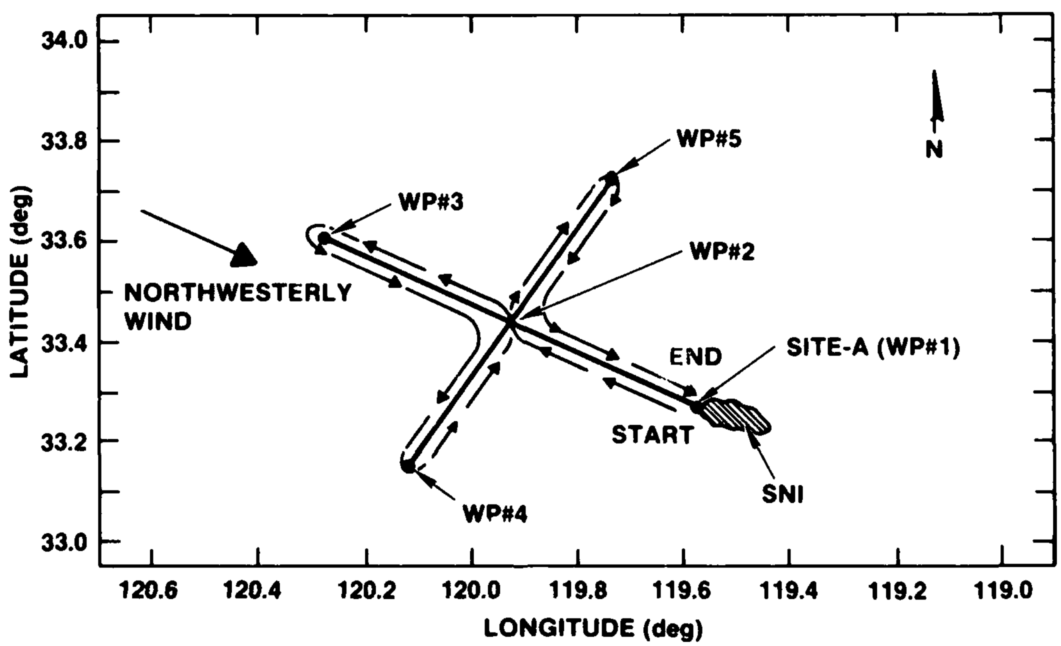

Figure 1. NOSC-prescribed flight pattern.

*FIRE—First ISCCP regional experiment.

MEASUREMENTS

Air temperature profiles taken at the four spiral locations (WP#1-4, figure 1) are shown in figure 2. Surface ATs at SNI were lower than those measured upwind and did not increase linearly with distance upwind from SNI. Above 300 m (within the haze/cloud layer), the AT at the island was bounded above and below by the upwind profiles. The inversion heights at all four locations were essentially the same. A sharper inversion did exist at SNI.

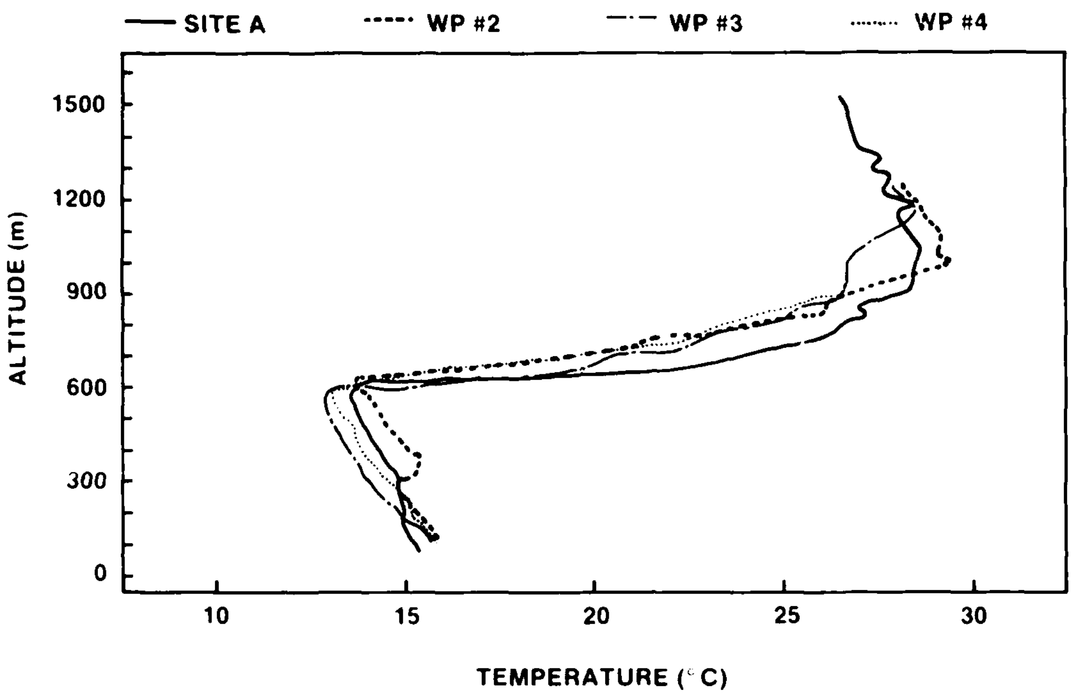

Figure 2. Air temperature profiles.

Profiles of relative humidity are shown in figure 3. The highest surface RH existed at SNI (97 percent) with the minimum (90 percent) at WP#2. These corresponded to the lowest and highest ATs respectively. Above 200 m and below the stratus tops, the SNI RH profile is bounded above and below by the upwind profiles. Just below the stratus tops, the RHs at all spiral locations were within a few percent of each other.

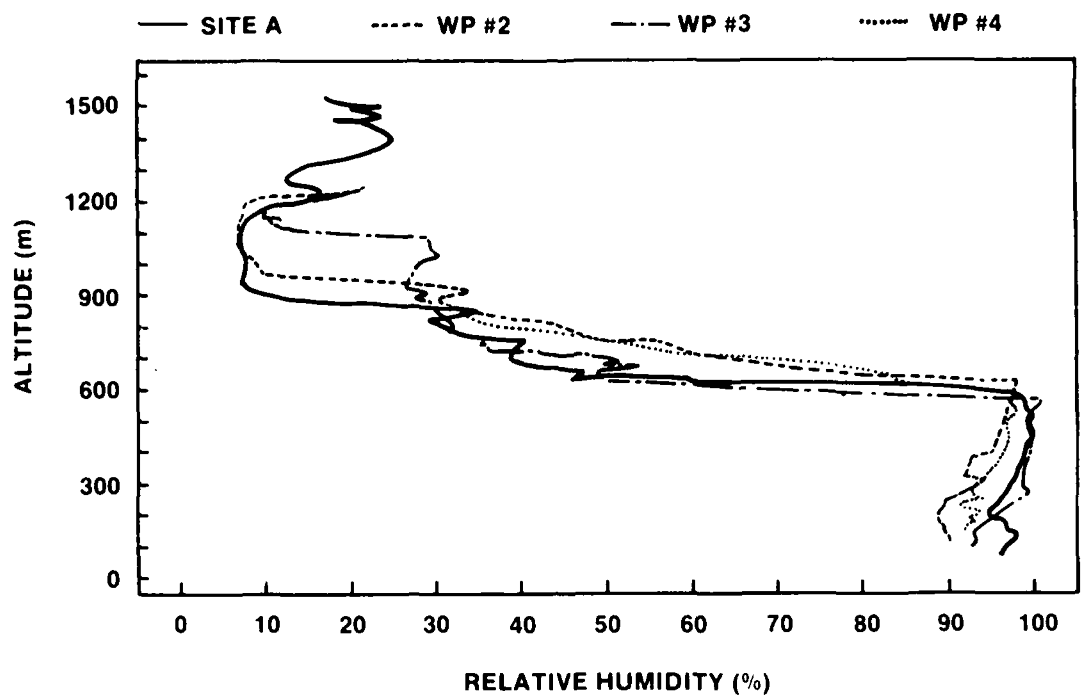

Figure 3. Relative humidity profiles.

Figure 4 shows the average-weighted aerosol radius (RBAR) as a function of altitude for each aerosol profile. At the surface, the upwind RBAR values were between 0.3 and 0.4 μm; while at SNI, RBAR was an order of magnitude higher. Above 300 m, and below the stratus tops, the SNI RBAR profile is bounded by the upwind profiles. The corresponding extinction coefficients, calculated using MIE theory for 0.53 μm, are shown in figure 5. The surface extinction coefficients at SNI are two orders of magnitude greater than that of the other upwind waypoints. Within the stratus cloud deck (above 300 m), the cloud aerosol extinction varied by as much as a factor of 10 between waypoints. The variations were not necessarily in any wind-related pattern.

The large increase in the surface RBAR and extinction at SNI could have resulted (1) from the growth of upwind aerosols as they were being wind advected toward SNI (a region of higher RH) or (2) by locally generated aerosols from island effects. If one assumes that the wind-advected aerosol grows with RH (reference 2), then the observed aerosol spectra profile at WP#1 would have existed at WP#2 (upwind) some time earlier. Profiles at WP#1 and WP#2 would differ then only by the increased size of the aerosol particles at WP#1 (assuming no other generation mechanism exists along the particle trajectory). Figures 6 and 7 show the comparison of the profiles of RBAR and extinction, respectively, that were observed at WP#1 with those that would have been observed had the aerosols of WP#2 grown with RH as they were transported toward the island (references 2 and 3). Calculated profiles were

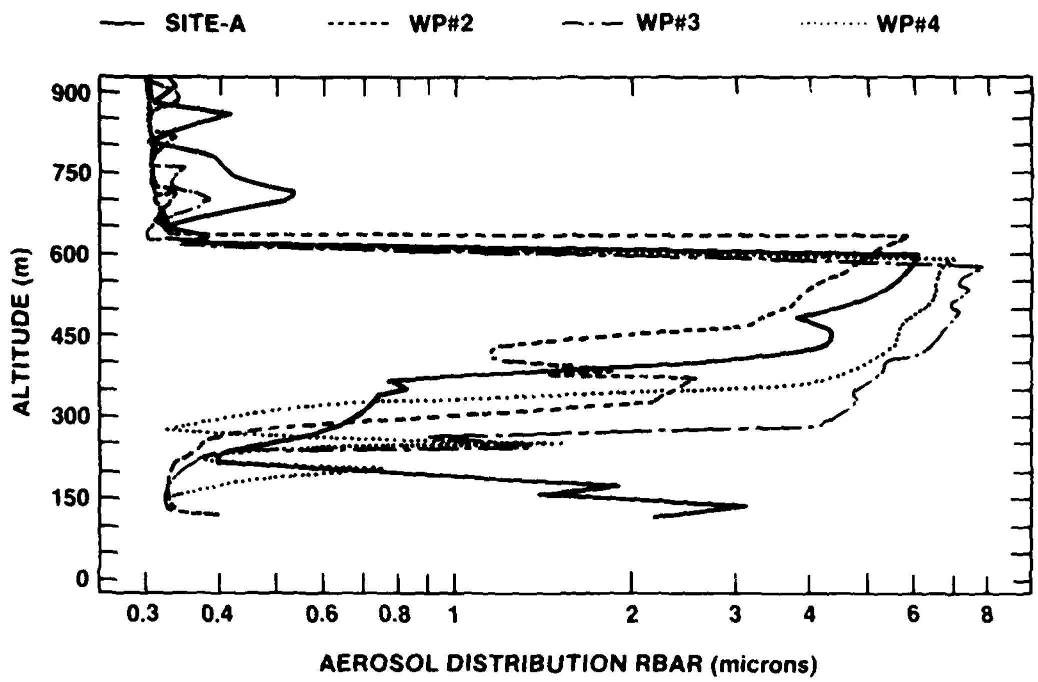

Figure 4. RBAR profiles.

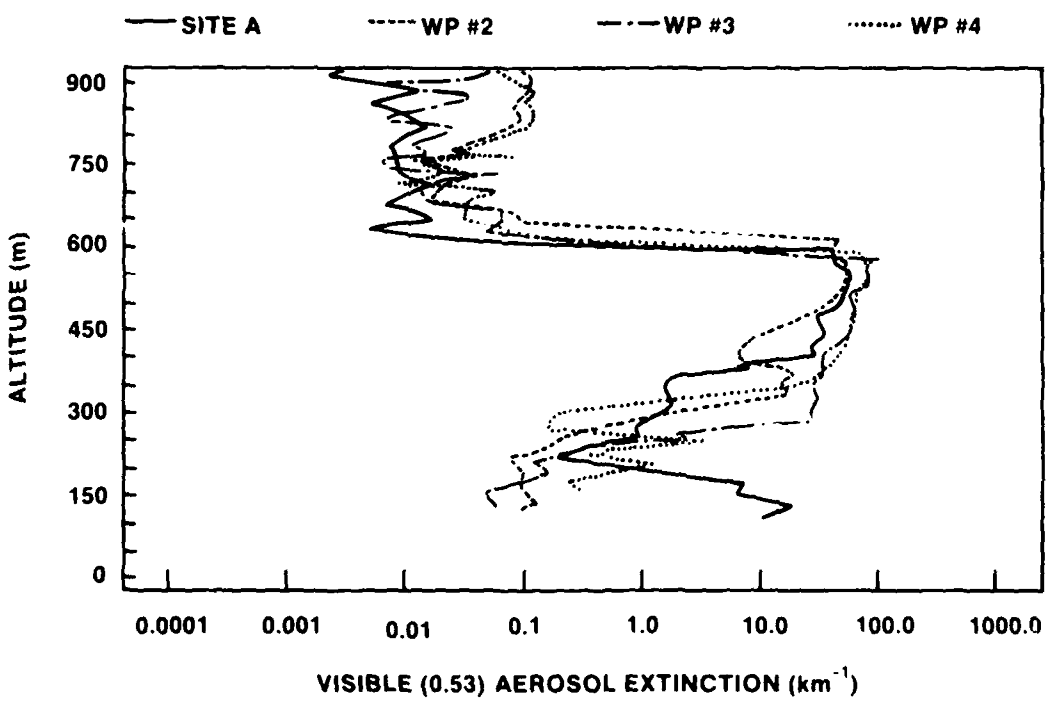

Figure 5. Aerosol extinction profiles.

obtained by transforming each aerosol spectra of the vertical profile at WP#2 according to the RH/growth mathematical relationship as given in reference 3. Stated mathematically

$$dN/dr = n(r)\,K\,\exp\,(0.66S/(1.058\text{-}S)), \qquad (1)$$

where

S = the standardized saturation ratio

n(r) = the reference aerosol spectra (WP#2)

r = the particle radius

K = the calculated constant to give the modification multiplier the value of unity for the WP#2 data

dN/dr = the transformed spectra according to the desired RH.

Figures 6, 7, and 8 show that the large increase in RBAR and extinction was not accounted for by the increase of RH about the island. (Figure 8 shows the correction factor for the increases of RH at WP#1.) The large surface values of RBAR and extinction at SNI must be attributed to a surface-based aerosol generation mechanism. This conclusion is further substantiated by the RBAR and extinction profiles of figure 5. Profiles of RBAR and extinction near the island decrease rapidly with altitude. Upwind of SNI, this rapid decrease with altitude is not observed.

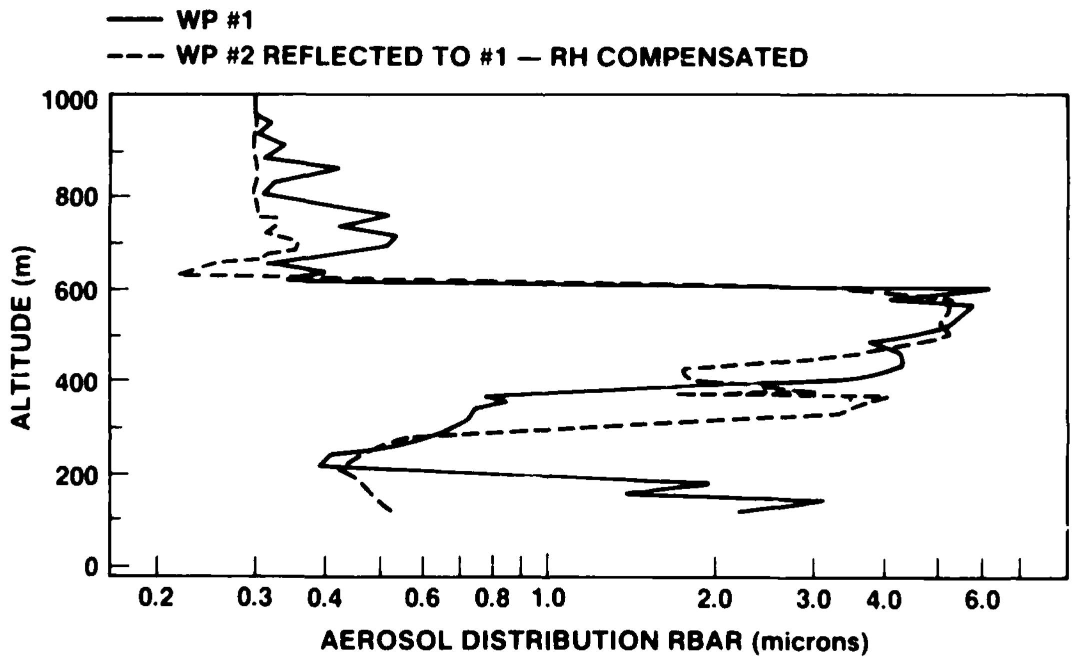

Figure 6. Comparison of RBAR profiles for SNI and WP#2 reflected to SNI for increased RH.

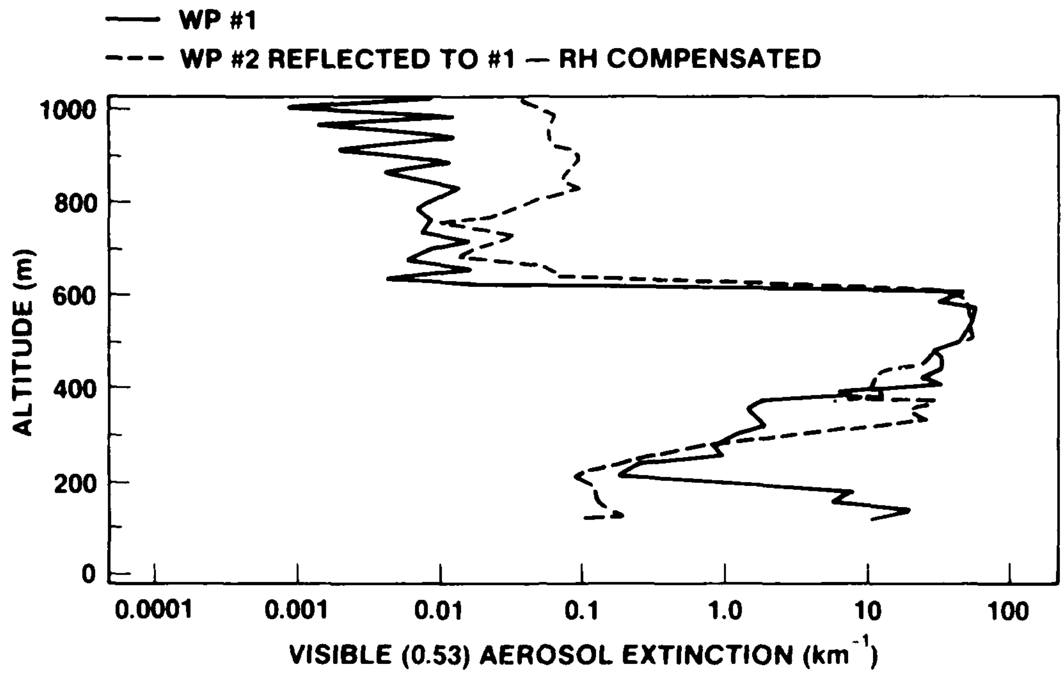

Figure 7. Comparison of aerosol extinction profiles for SNI and WP#2 reflected to SNI for increased RH.

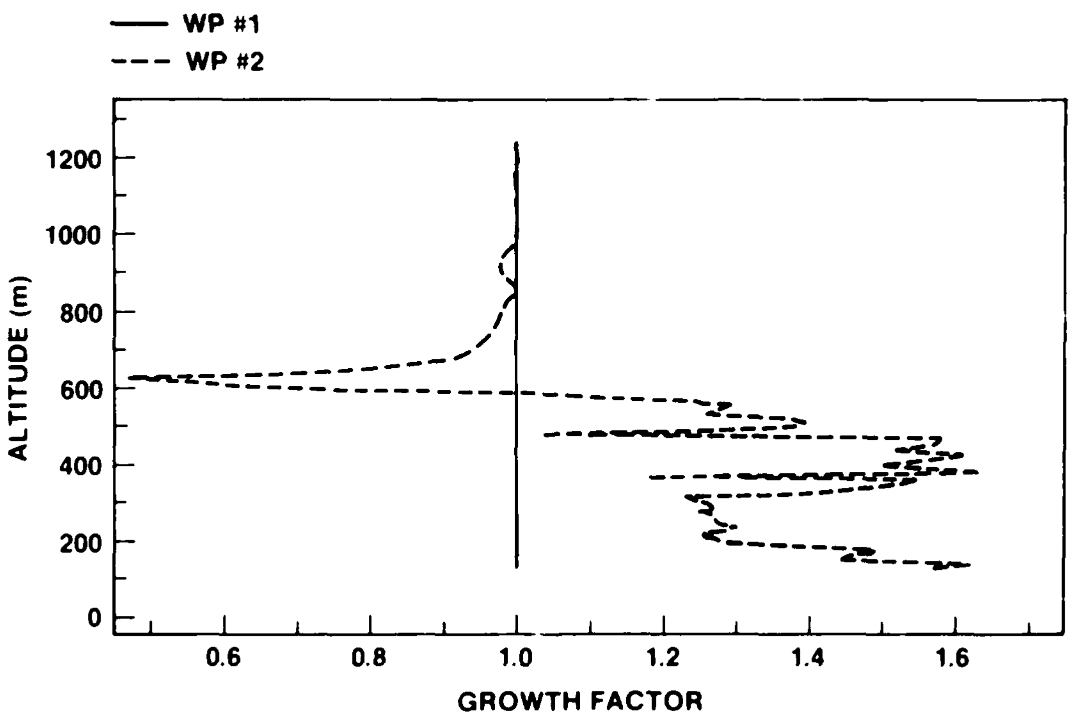

Figure 8. Correction factor for referencing WP#2 profiles to WP#1.

The total integrated optical depth for 0.53 μm as a function of altitude is shown in figure 6 for each way point. The higher optical depths occurred upwind of SNI at way points 3 and 4. At SNI, where the surface aerosol extinction was the highest, the total optical depth was next to the lowest. The major contribution to the optical depth occurred within the top 100 meters of the stratus deck. Aerosols below this height did contribute but not as significantly as did the stratus top. This is evidenced by the slight increase in the optical depth at the bottom of the SNI profile. This slight increase resulted from the large increase in the number of surface-based aerosols (figures 5 and 9).

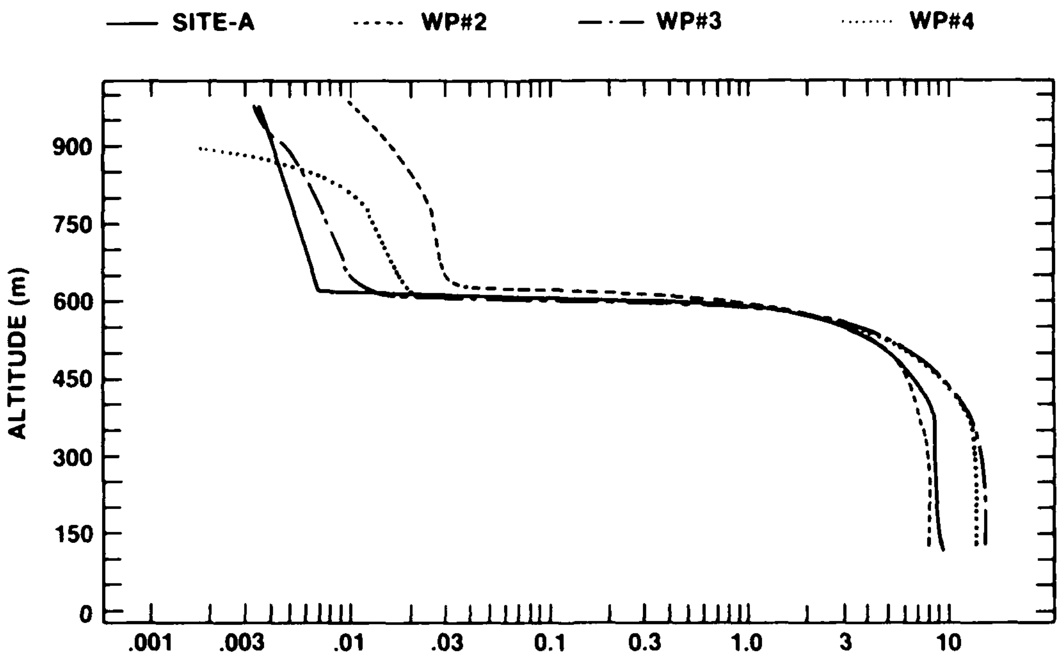

Figure 9. Optical depth profiles.

Horizontal profiles of sea surface temperatures (see figure 10 for an example) showed a general increase in temperature with distance upwind of SNI. Large fluctuations of SSTs were superimposed on this profile with scale sizes in the order of 5 to 10 nmi. In general, the sea surface temperatures were warmer than the air temperatures.

Cloud-top temperature profiles showed CTTs decreasing upwind of SNI in contrast to the SST observations. This decrease in upwind CTTs seemed to be caused by vertical mixing (SST warmer than the AT), thus resulting in upwind stratus tops being at a higher elevation. However, the stratus tops were within 100 ft over the entire flight pattern.

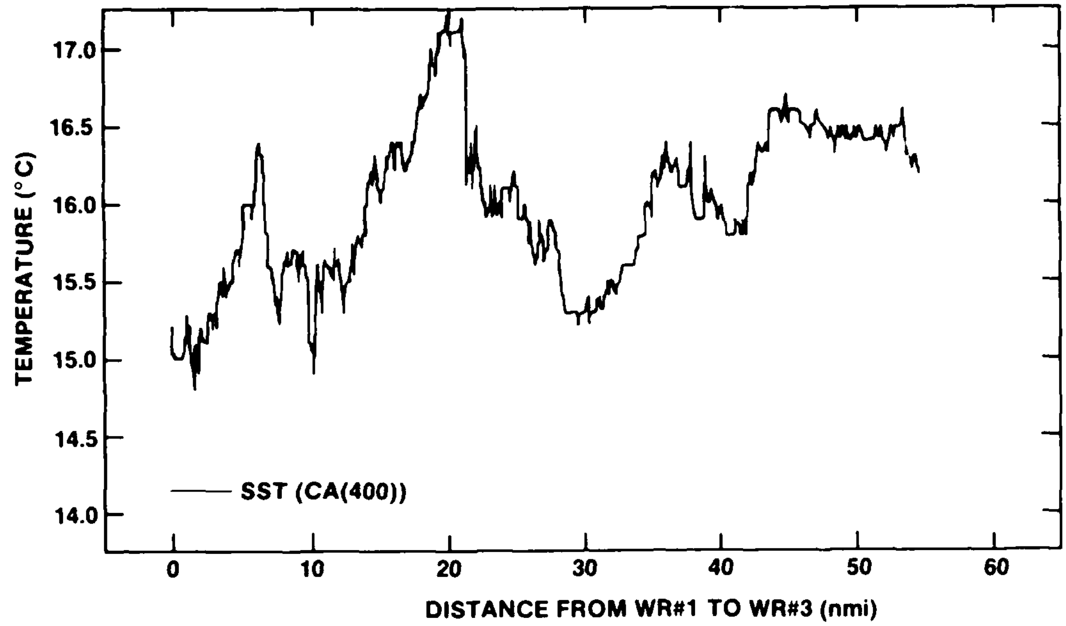

Figure 10. Sea surface temperature profiles.

CONCLUSIONS

Profiles of AT, RH, RBAR, and extinction taken "at" and "upwind" of SNI do show differences between the so-called open ocean conditions and those taken near the island. The observed differences cannot, however, be uniquely identified to a specified island effect, especially since the upwind fluctuations bound the SNI measurements.

Total optical depths measured at SNI are not strongly affected by the surface-based aerosols generated near the island; thus, these optical depths could realistically represent open ocean conditions. However, in this case, if one were to use the SNI measurements to predict open ocean ship-to-ship EO propagation conditions, significant errors would result in the total horizontal extinction. This extinction error would result from the increased number of surface aerosols near SNI which were not characteristic of the open ocean conditions.

Sea surface temperature measurements taken at the island will not in general represent upwind open ocean conditions. Also, since CTT varied appreciably along the upwind radials, measurements of CTT over the island may not represent actual open ocean CTT.

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